

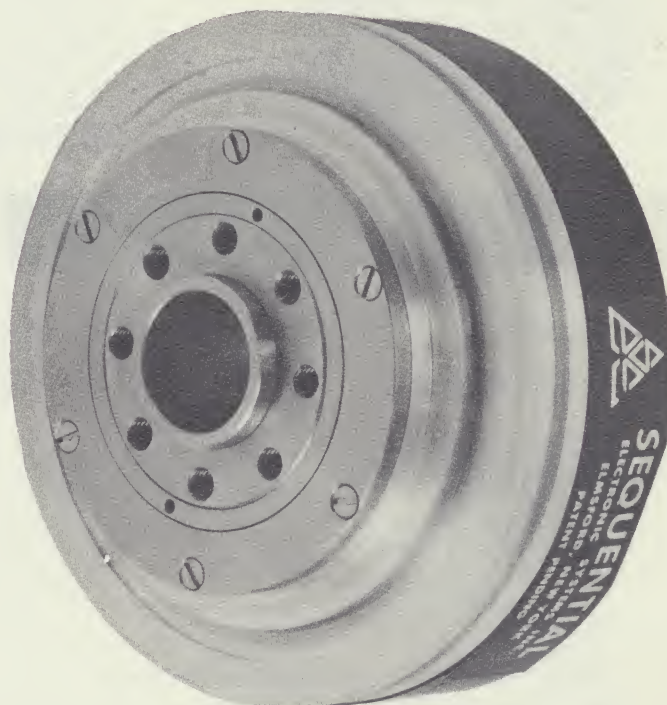
SEQUENTIAL ELECTRONIC SYSTEMS

OPTI-SCAN

INCREMENTAL OPTICAL ENCODER

FEATURES

- Resolution to 2^{16} in 3½ inch diameter housing
- Signal-to-noise ratio greater than 26 db
- Operating temperature range from -55°C to $+71^{\circ}\text{C}$
- Sine-cosine outputs available for multi-speed resolver servo applications
- All electronics self-contained in encoder housing
- Integrated circuit assemblies
- Printed circuit interconnections
- Modular construction
- Unique locked-beam optical readout
- Plug-in lamp module, field replaceable
- Fiber optic disc illumination
- No trim adjustments
- In-field repair capability
- Outputs unaffected by power supply variations and bulb aging
- 3 year lamp life
- Projected electronics MTBF — 6 years
- Meets all applicable MIL-Specs



SERIES 351

DESCRIPTION

Sequential OPTI-SCAN "pancake" incremental encoders are uniquely designed for gimbal frame mounting. The encoder bearing, by supporting the gimbal shaft, functions as the gimbal pivot. By including the readout electronics and level detectors entirely within the encoder housing, additional space is saved and greater design flexibility provided.

OPERATION

The code track inscribed on the integral optical disc has a maximum density of 2^{11} (16,384) clear and opaque radial sectors. On special orders requiring limited operating temperature ranges, the maximum resolution increases to 2^{19} (65,536) clear and opaque radial sectors. A second track on the disc provides a once per revolution index mark. This index mark is precisely synchronized to maintain a fixed spatial relationship with the high density track.

A single 5 volt incandescent lamp is used. Reference light beams are d.c. excited and transmitted to the readout stations via incoherent fiber optic bundles.

The OPTI-SCAN optical readout (patent pending) employs a locked beam technique to generate the quadrature-phased sine-cosine outputs. The locked-beam approach insures that these outputs exactly maintain their phase relationship independent of shaft position and gives an output signal-to-noise ratio greater than 26db. It also insures that the average dc output level, about which the signal varies, is maintained at zero for

wide variations in both the lamp and amplifier power supplies. This feature guarantees constant duty cycle at the level detector outputs. The locked beam also extends the useful life of the encoder and permits in-field replacement of the plug-in lamp module without requirement for trim adjustments.

A pair of silicon photocells, connected back-to-back, are utilized in each channel (sine, minus sine, cosine, minus cosine) to generate the sinusoidal output signals. These signals vary about a true zero dc voltage level. For example, with a 2^{14} primary disc, discrimination of the two null crossings per cycle of the signal from each of the two quadrature channels provides angular resolution of 2^{18} (65,536) increments per shaft revolution with a minimum accuracy of $\pm$ one count at all shaft positions. The readout electronics associated with each output channel and the zero index channel are wholly contained within the encoder package. This includes the electronics which generate the sinusoidal output and the zero index signal, and the level detectors that generate the output dc levels (square wave). All electronics in the encoder housing are integrated circuit assemblies.

APPLICATIONS

OPTI-SCAN "pancake" encoders are presently field operational. The electronic circuits employed were developed for the military and use severely derated components assuring long MTBF. The projected MTBF of the electronics is 6 years. Lamps are derated to give a minimum rated life of 3 years.

An optical signal generator similar to that used for generating the sine-cosine outputs is provided for applications requiring the zero reference. This signal generator provides an accuracy and stability of the zero reference crossover equal to those of the count channels. By incorporating this technique a once per revolution signal is formed at a fixed shaft position and this fixed position corresponds to any desired position within one cycle of the sine-cosine count channels. The amount of hysteresis required in the count channels and the zero reference channel can be varied depending upon the application.

OPTI-SCAN encoders replace the commonly used synchro generators providing simple and direct analog-to-digital conversion. The encoder requires only elementary logic to form the clockwise and counterclockwise pulses. These pulses may be used as inputs to a computer or counter to provide shaft position data in digital form. Separate packages are available for the electronics required to convert the level detector outputs to two line count information, and the zero reference output to a narrow pulse.

OTHER ENCODERS

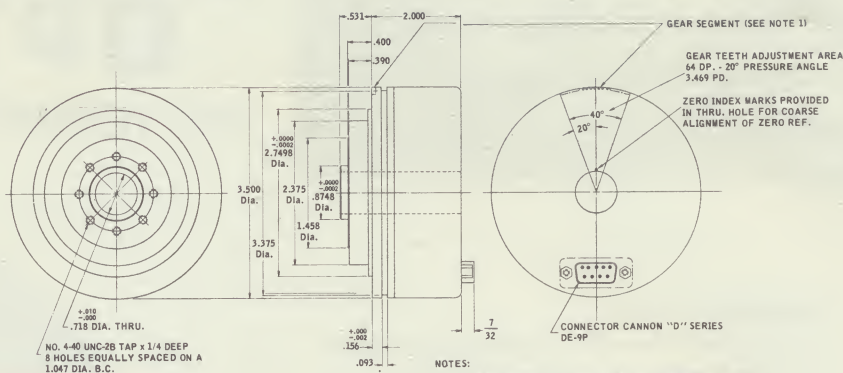
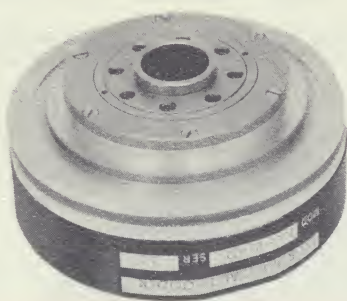
For higher resolution requirements, Sequential supplies incremental encoders up to 2^{20} . These encoders employ a larger disc and are larger in diameter.

Sequential also produces a line of direct reading, photo-optical encoders which produce electrical pulse outputs in parallel, cyclic binary, natural binary or other codes corresponding to angular shaft position.



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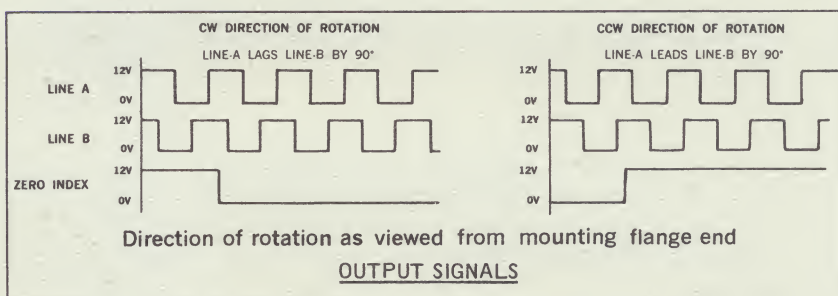


SPECIFICATIONS

Resolution (1)	Up to 65,536 zero crossings/ shaft rev.	Maximum starting torque (over operating temperature range)	4.0 in-oz
Optical Disc Accuracy	0.2 Arc seconds from one line to any other arbitrary line around a revolution	Maximum recommended mechanical load (Applied at end of shaft) (5)	
Output Signal Accuracy (2) (maximum error between any two zero crossings)	± ½ bit	Axial	75 lbs.
Output Signals (Sine-cosine channels and zero index) (3)		Radial	75 lbs.
Amplitude	12 ± 2 volts	Weight	3 lbs.
Rise and Fall Time (10% to 90% points)	0.2 microseconds	Maximum Bit Rate for Full Accuracy (6)	30,000 cps
Polarity (4)	positive	Maximum non-operating (slewing) speed	3000 rpm
No Signal output	± 0.2 volts	Temperature Range	
Output Impedance	less than 4000 ohms	Operating	-55°C to +71°C
Output Signal-to-Noise Ratio	26 db min.	Non operating	-65°C to +85°C
Input Power		Humidity	97%
Lamp Power		Altitude	50,000 feet
Voltage	5 ± 0.25 vdc	Vibration	
Current	225 ma	Operating	1.5g @ 10 to 55 cps, per MIL- E-5272C, Procedure XI
Regulation	± 3%	Non-Operating	10g @ 5 to 55cps per MIL-E- 5272C, Procedure XI
Ripple	0.1%	Shock (non-Operating)	Will withstand 9 shocks of 30g, each 11 ± 1 millisecond dura- tion
Polarity	positive or negative	Life	
Amplifier Power		Bearings (minimum 3000 rpm)	2 x 10 ⁸ revolutions
Voltage	plus and minus 12 ± 1 vdc	Lamp (minimum rated)	3 years
Current		Amplifiers (projected MTBF)	6 years
+12 vdc	65 ma		
-12 vdc	65 ma		
Regulation	± 3%		
Ripple	0.1%		

Notes:

- Resolution to 2" in 3½ inch housing available for operation over limited temperature range
- The output signal accuracy does not include the quantizing error of ± ½ bit
- Count channel electronics to convert the analog signals to CW and CCW pulses which may be used as inputs to a computer or counter are available in an external package. This external package also processes the zero index signal, providing a narrow output pulse
- Negative polarity outputs are available
- Both solid and hollow shaft units are available
- Higher bit rates available



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ELECTROMECHANICAL COMPONENTS & SYSTEMS DESIGN

THE SOURCEBOOK OF DESIGN IDEAS IN APPLIED ELECTROMECHANICS

JITTERLESS PHOTO RECON SYSTEMS

SEQUENTIAL ELECTRONIC SYSTEMS, INC.

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JITTERLESS PHOTO RECON SYSTEMS

Eliminate the jitters without gearing or speed reducers

A problem of utmost concern confronting the military today is the ability to produce reconnaissance photos with sufficient detail to fully evaluate the terrain over enemy territory. The basic problem results from the inability to move film very slowly and accurately and smoothly. The "jitter" created by the drive as the film travels over the capstan, reduces the resolution to a point where much of the information being sought is lost.

Spiroid gears, metal to metal rollers and other similar speed reducers now in use have proven inadequate. M. Schiller, President, Sequential Electronics Systems, Inc. of Elmsford, New York has introduced two film drive systems that completely eliminate the necessity for gearing or speed reducers of any kind. The Sequential systems allow the operator to move film at any speed and maintain an instantaneous position accuracy of better than 1 arc second.

Sequential supplies airborne (explosion proof) and ground processing equipment that provides the ability to photograph terrain with a resolution which is greater than the present "state-of-the-art". In order to accomplish this end, two different systems are offered.

• *The basic Sequential Film Drive System* according to Mr. Schiller, consists of a Sequential Film Drive Motor and an FPL Control System. The motor incorporates a direct dc torquer and a capstan assembly which is an integral part of one end of the motor shaft. A high resolution optical encoder is integrally assembled to the other end of the shaft. The Frequency Phase Lock (FPL) Control System uses electronics to provide ultra precise speed and phase control of the motor shaft. Absolute speed synchronization is an inherent property of this system's mechanization, and can be achieved in the presence of drastic variations

in supply voltage, load torque and environmental conditions.

• *The advanced Sequential system* is the Band-Scan FPL Control System which offers the ultimate in precision motor control. It retains all the advantages of the basic FPL System in terms of simplicity of implementation and sophistication of control, but in addition completely eliminates all inherently limiting characteristics (relating to control bandwidth and operational range) of sampled data phase locking systems that derive feedback information from a pulse-rate tachometer. Band Scan utilizes miniaturized Band-Scan FPL control electronics, a miniaturized Band-Scan Reference Generator, and an electro-optical modular Band-Scan Readout which integrally mounts to the control motor.

OPERATION OF THE BASIC FPL SEQUENTIAL FILM DRIVE SYSTEM

The angular speed and phase of the motor shaft are measured by a Sequential Optical Encoder, integrally mounted to the drive motor shaft, which produces N pulses per revolution. The tachometer contains a coded-disc, having a track with N opaque and N alternate clear segments, mounted to the motor shaft. The master discs are manufactured on an automatic circle dividing machine, developed by Sequential, which can pro-

duce coded-discs with a line accuracy of 0.33 seconds of arc. A light source is focused through a reticle, with the same line density as the coded-disc, onto the track of the disc. A photocell, mounted on the opposite side of the disc, senses the light as it passes through the track. The photocell output is amplified by an optical preamplifier mounted in the tachometer housing. As the disc rotates, the light is alternately passed and blocked by the segments on the track. The output of the preamplifier is a sinusoidal signal that repeats N times per revolution. This output signal is passed to pulse shaping circuitry that produces a sharp tachometer pulse at each positive-going, zero cross-over of the sinusoidal signal. Thus, N tachometer pulses are produced for each revolution of the motor. At any speed, the tachometer pulse frequency, in pulses per second, is given by $\Omega N/60$ where Ω is the motor speed in rpm.

A reference pulse train (Fig 1) is generated from a Reference Frequency Signal input whose frequency is exactly equal to the frequency that the tachometer signal would have when the motor is rotating at the correct speed. This reference signal and the tachometer signal are fed to the computer. The computer contains frequency-lock logic which compares the frequencies of these two signals and generates an error signal if there is a frequency difference. The magnitude and polarity

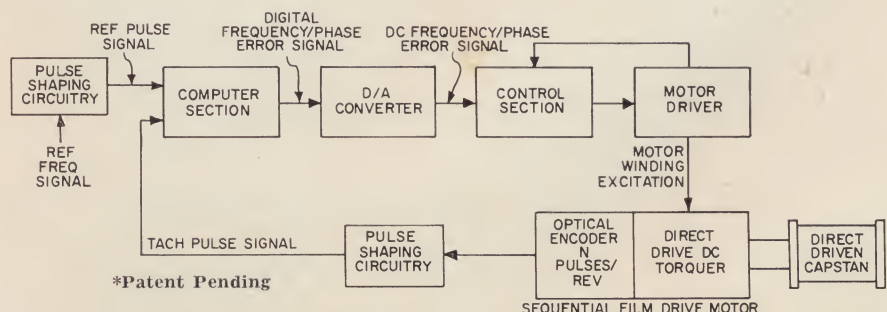


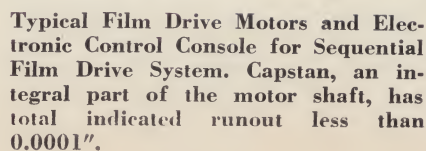
Fig 1 — Frequency Phase Lock (FPL) Control System.*

If a torque disturbance is applied to the capstan, the phase angle be-



Values of K_D achievable with the proper dynamic stabilization are in the range of 20-40 db. These electrical gains coupled with the extremely high sensitivity of the optical tachometer determine open-loop gains on the order of 1,000,000 (120 db) radian/second/radian throughout the control bandwidth.

The practical aspects of such gain-bandwidth capabilities are that the effects of undesirable torque perturbations, arising either internal to the control motor, or externally applied by the load mechanism, are reduced by a minimum of 140 db within the spectral band of 0 to a minimum of



3 kc/s. This allows the utilization of standard dc commutating ball bearing torque motors for a degree of super-precision that up to now has been considered impossible to achieve. The Band-Scan FPL System can mechanize any type of ac or dc ball bearing or air bearing rotary drive. With this system the need for expensive precision air-bearings is almost entirely eliminated. A possible exception would come only in the most stringent mechanical requirements where drive shaft runout must be held to less than 25 micro-inches TIR.

Reference inputs to the Band-Scan Reference Generator are set by a pulse train whose frequency directly corresponds to commanded motor speed and whose phase relates to

drive shaft position. The standard speed-frequency conversion rate is such that motor rpm is

$$\Omega = Rf$$

where f = reference frequency and
 R = conversion ratio selected for a given application.

The reference generator samples and stores speed/phase command information. Updating of the coordinates in storage is once/cycle of the reference. The interrogation rate of the generator for information fed into the Band-Scan FPL is automatically made compatible with the conversion rate of the Band-Scan Readout.

For motor back-to-back speed/-

phase control, the generator is not required and the Band-Scan Readout on the master motor functions as the command for the slave motor.

Natural binary coded or decimal rate and position information is directly available from the Band-Scan FPL for external readout on a counter.

The Sequential systems described are presently operational in both ground and airborne equipment for gathering, processing, transmitting and recording graphic information. Other applications include reconnaissance, facsimile, photo transmission, radar and infrared data recording, optical processors, and optical information recording. ■

Other SEQUENTIAL products include . . .

Camera Synchronization Systems
Film Drive Systems
Tape Drive Systems
Photo Reconnaissance Drive Systems
Magnetic Drum Synchronization Systems
Air Bearing Centrifuges
Rate/Position Control Systems

Facsimile Recorders & Scanner Drive Systems
Incremental Optical Shaft Angle Encoders
Whole Word Natural Binary Optical Encoders—Resolution to 2^{20}
Air Bearing Rate Tables
Air Bearing Gyro Test Tables
Optical Resolvers
Indexing Systems

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